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Temperature Measurements for Investigation of the Urban Heat Island in Salt Lake City -

Data Report for the DOE CBNP URBAN Experiment, Oct. 2000

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Temperature Measurements for Investigation of the Urban Heat Island in Salt Lake City:

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1. Introduction

Measurements of temperature and position were collected during several nights from an instrumented van on routes through Salt Lake City and the rural outskirts. The measurements were taken during one week of the Department of Energy Chemical and Biological National Security Program (DOE CBNP) URBAN2000 Field Experiment conducted in October 2000 (see Shinn et al., 2000 and Streit et al., 2001). A thermistor-type temperature probe and GPS were affixed to the outside of a cargo van and used to record temperature and position directly to two PC laptops. The instrumented van was driven over three primary routes, two including downtown, residential, and "rural" areas and a third that went by a line of permanently fixed temperature probes (Allwine et al., 2001) for cross-checking purposes. Each route took from 45 to 60 minutes to complete. Four nights of measurements are presented in this data report for the period Oct. 22-26, 2000.

The measurements reported herein are intended to supplement the meteorological measurements taken during the URBAN2000 Field Experiment. The temperature measurements will be useful for assessing the importance of the urban heat island phenomenon in Salt Lake City and for testing the urban canopy parameterizations that have been developed for regional scale meteorological codes as part of the DOE CBNP program. Initial analyses indicate that there is a temperature difference of from 2-5 °C between the urban core and nearby "rural" areas. Analyses also suggest that there are significant fine scale temperature differences over distances of tens of meters within the city and in the nearby rural areas.

We begin our report with a description of instrumentation and software used to collect the data. We then describe the routes and include photos showing the vegetation, terrain, and urban landuse for points along the route. A section on the prevailing weather conditions during each night of the experiment follows. Results are then presented, including timeseries plots of temperature and vehicle speed and maps with superimposed temperatures. Lastly, a summary is given along with information on data format and where the data can be obtained.

2. Instrumentation and Software

Air temperatures in Salt Lake City and surroundings were obtained by driving an instrumented Chevrolet cargo van over several standard routes in the Salt Lake City area. The temperature and position data were measured with a thermistor probe and a GPS unit, respectively. The thermistor-type temperature probe was mounted on a 1.5 cm diameter PVC sting and the GPS unit was taped to the roof. The sting was affixed to the van between the front and rear passenger side doors with the temperature probe approximately 25 cm above the vehicle roof (Fig. 2.1). The thermistor was approximately 2.5 m above street level.

The temperature data were taken using a YSI 4600S (Transfer Standard) Precision Thermometer in conjunction with an "in-house" Matlab data acquisition program run on a PC laptop. Figure 2.2 shows a sample output from the Matlab data acquisition software. Time and temperature data were acquired through a serial (RS-232) interface at a rate of one sample every 524 milliseconds. The time constant of the YSI 4600S is one second in an oil bath and five to ten seconds in air, the resolution is 0.01 °C, and the accuracy is ± 0.025°C from 0° to 50°C. Our unit was calibrated at five points with a YSI 052 Bird Cage Air Probe and has certified NIST traceability. The calibra-

Figure 2.1 Van with GPS unit and temperature probe. The inset shows a close-up of the protective bird cage basket that shields the thermistor-type temperature probe.

tion readings, all in stirred oil baths, are as follows:

Temperature	4600S Reading
-40.000C	-39.993
0.000C	0.005
25.000C	24.997
40.000C	39.990
70.000C	69.992

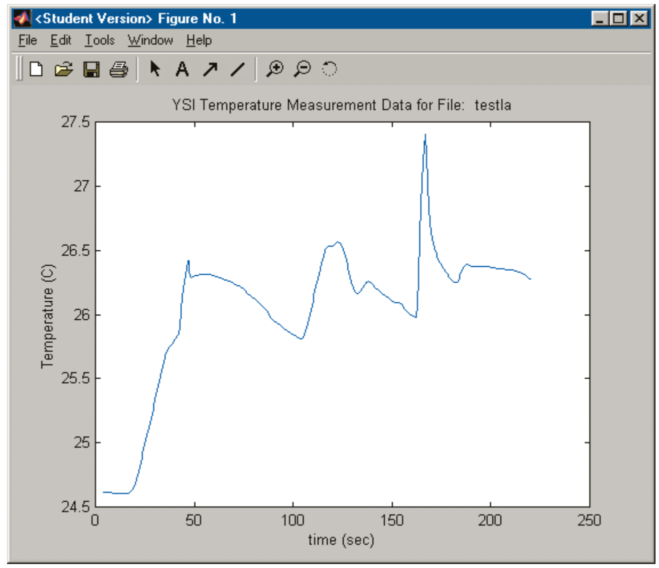

Figure 2.2 - Temperature data acquistion system real-time display using MATLAB software.

The spatial-temporal position of the van was obtained with a DeLorme Earthmate GPS (www.delorme.com). The position, time, and velocity data were saved to a file using DeLorme's Topo U.S.A. 2.0 software. The GPS unit and software were run on a second PC laptop. The GPS and laptop interfaced via a serial connection. The DeLorme software allowed us to see our route in real time (Fig. 2.3). Satellite accessibility limited the data rate of the GPS system and caused it to be slightly irregular, ranging between 0.25 and 1 Hz. The horizontal accuracy of the GPS varied between 10 and 15 meters while moving. The speed range over which the van traveled was from 10 to 30 mph with frequent stops. The Earthmate GPS was powered by four AAA batteries limiting the unit's running time to approximately 8 hours.

The clocks on both of the PC laptops were synchronized to the local time. Due to the different sampling rates of the GPS and thermistor probe, the temperature and location data were down-sampled and interpolated to create a two-second interval time series. This 0.5 Hz data is available on the CBNP URBAN2000 web site hosted by Lawrence Livermore National Laboratory (LLNL) or directly from the authors on CD (see Section 5). The raw, unfiltered GPS and temperature data can be obtained by request from the authors. The temperature data has not been converted to potential temperature or virtual temperature. One could use elevation data from terrain contour maps and relative humidity data from nearby meteorological stations along with the vehicle position and time series data sets in order to convert the temperature to potential and virtual temperatures.

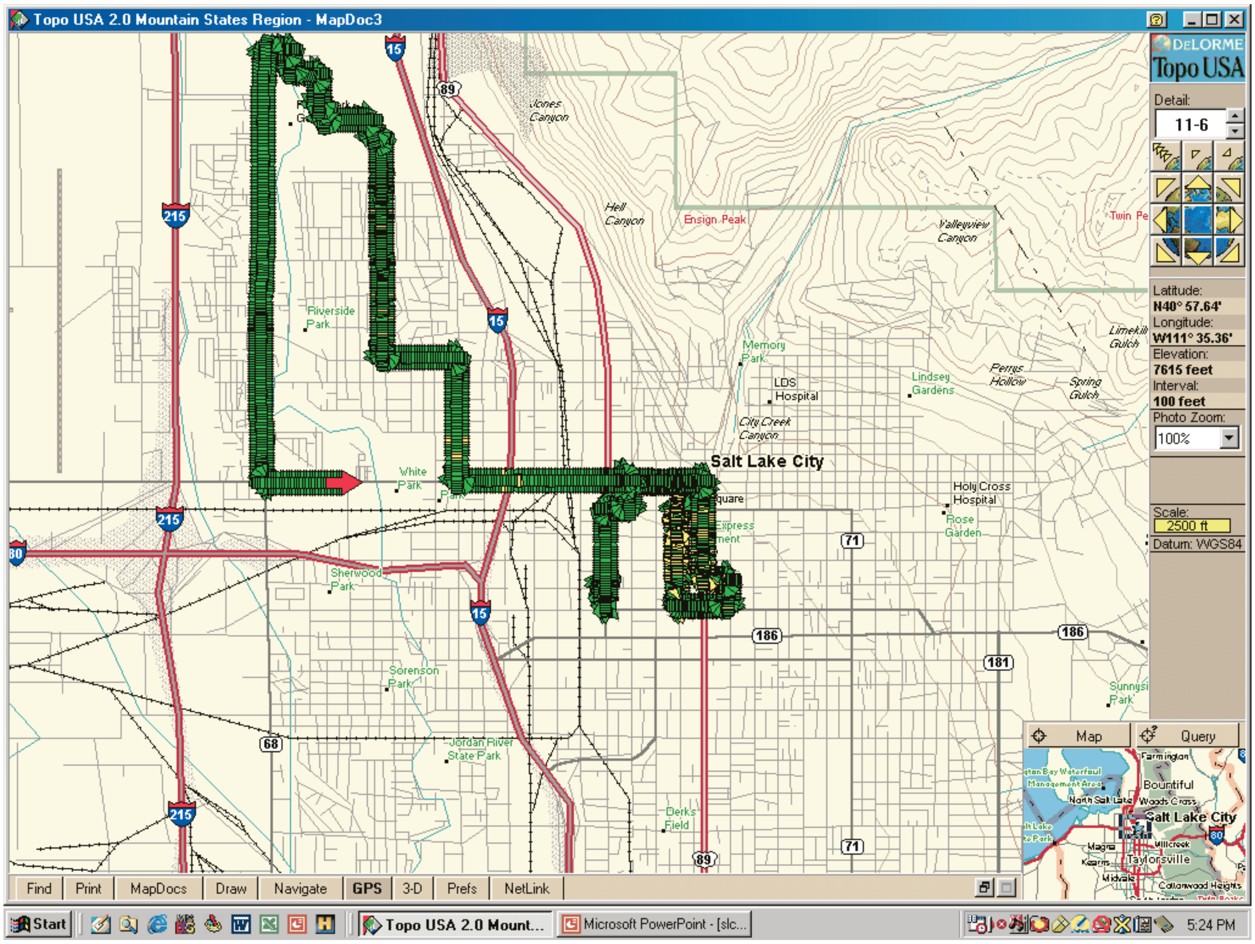

Figure 2.3 GPS-derived van route depicted using the DeLorme TopoUSA software.

3. Route Description

We chose two major routes that each took about an hour to drive and covered the urban core, light industrial zones, strip malls, residential neighborhoods, and then rural areas. These two routes are depicted in Figures 3.1 and 3.2 along with annotations depicting the different landuse zones. Occasionally, a third route was driven that passed by an array of temperature sensors (called HOBOS) mounted on telephone poles by the Pacific Northwest National Laboratory (PNNL) team (Allwine et al., 2001). The data collected over this route were intended for cross-check purposes.

As indicated on the maps, the elevation in the downtown core is about 4300 feet above sea level. To the west it is relatively flat, with a maximum elevation change of about 70 feet. To the east are the foothills of the Wasatch Range. There is a gentle rise of about 100 feet as one travels east from the downtown area past the HOBO sensors. As the University of Utah is approached the elevation change increases, reaching about 4700 feet at the end of our route. One can also see several canyons that open into the city, including City Creek Canyon to the northeast of the downtown core, and Dry Creek and Red Butte Canyons to the north and northeast of the University of Utah, respectively. Just off the map is Emigration Canyon, located just south of the University, and about two miles further south is Parley’s Canyon.

Most of the routes included a trip through the downtown core (Figs. 3.3 and 3.4). The buildings in this area extend from a few stories to tens of stories and cover a relatively small area of about ten square blocks. In order to compute an urban-rural temperature difference, we drove two routes that took us to two different “rural” areas. On one route, the rural area began near a golf course and city park, and included pasture and marshy land, but a refinery bordered the "rural" area to the north, residential neighborhoods to the south, and the freeway to the east (Figs. 3.5-3.7). The second “rural” route was farther out of the city to the west, and included larger tracts of vacant vegetated land, but there were still warehouses intermittently interspersed throughout (Figs. 3.8 and 3.9). We refer to the first rural route as the “Golf Course” route and the second rural route as the “Brighton Creek” route.

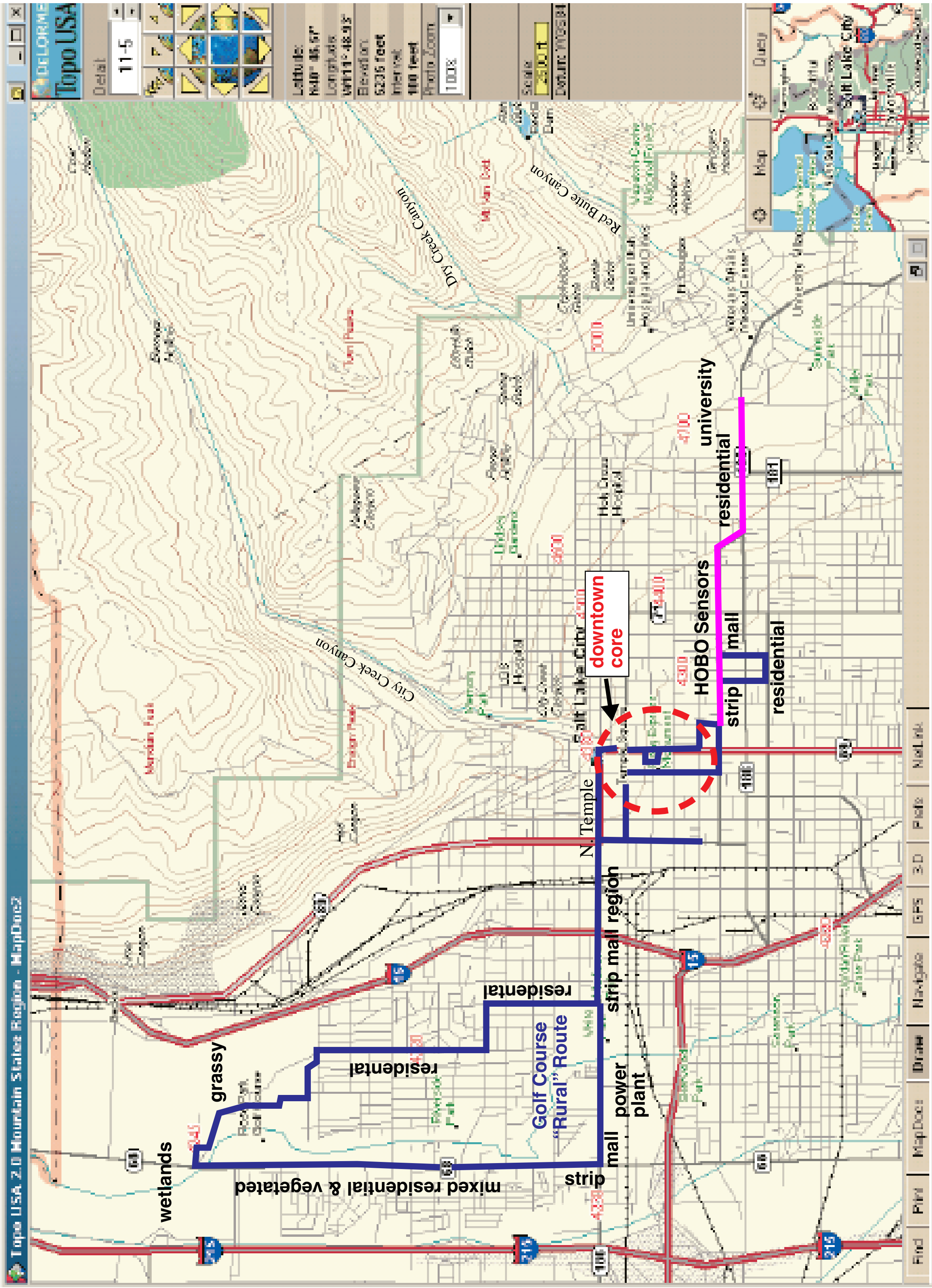

Figure 3.1 Typical routes driven during the study overlaid onto topography and street maps of Salt Lake City and vicinity.

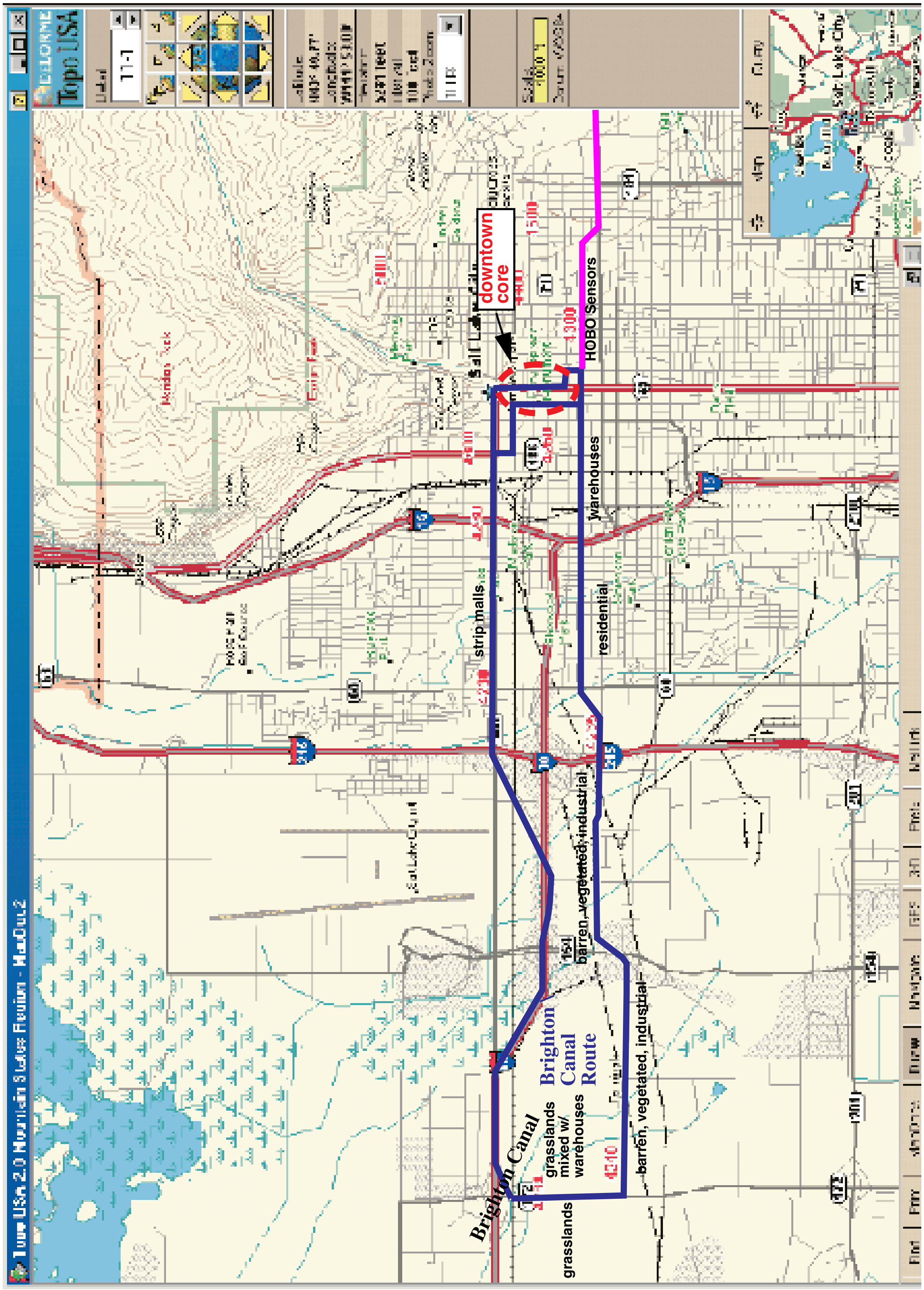

Figure 3.2 Typical routes driven during the study overlaid onto topography and street maps of Salt Lake City and vicinity.

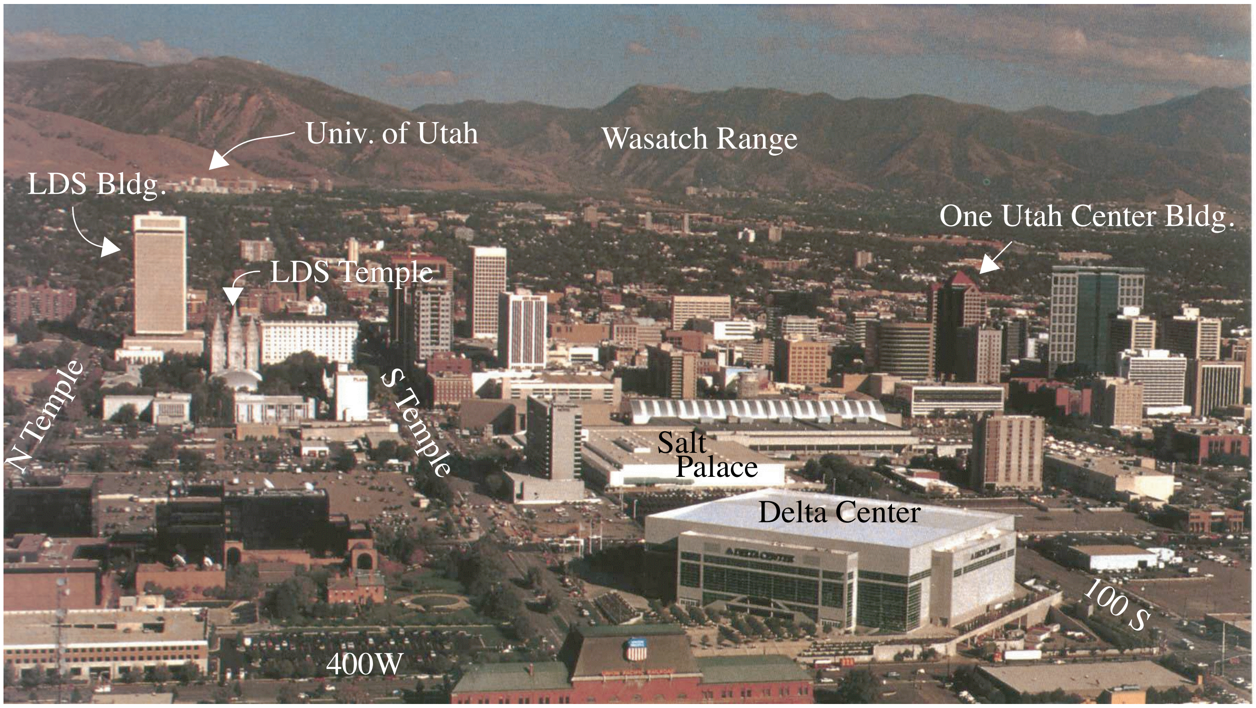

Figure 3.3 View of downtown Salt Lake City looking towards the east. The downtown route extended to N. Temple on the north and to 400S on the south (just to the right of the tall buildings on the right hand side of this figure). North-south routes were usually driven down Main St. and State St. (Hghwy. 89) which run left to right in the midst of the tall buildings in the photo.

Two light industrial and warehouse zones were included on the routes, one in the region near the railroad tracks that run north to south on the western side of downtown Salt Lake City and another closer to the rural area on the southern half of the Brighton Creek route. The residential neighborhoods had tree-lined streets and included well-watered lawns and vegetation (e.g., Fig. 3.10). The strip mall sections of the route along N. Temple west of the railroad tracks included wide avenues with small strip malls, interspersed with parking lots, fast food restaurants, banks, and gas stations (Figs. 3.11 and 3.12). Figure 3.13 shows an electric power plant that may contribute to local warm spots along our N. Temple route given southerly wind directions (see Section 4).

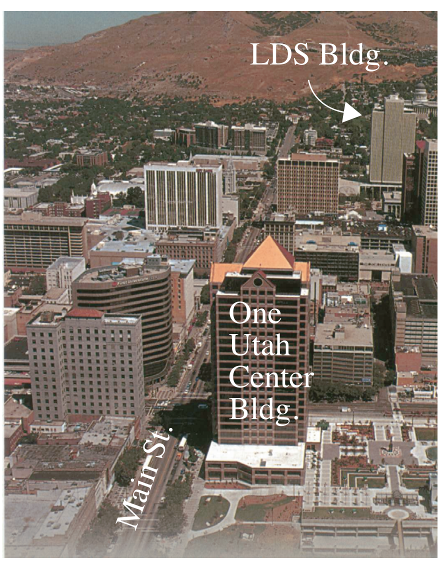

Figure 3.4 View of downtown SLC looking north.

Figure 3.5 View looking towards the east from 1200W in the “rural” area on the “Golf Course” route. Rosewood Park is in the foreground, the Wasatch Range in the background.

Figure 3.6 View looking north on 1200W in the “rural” area on the “Golf Course” route. Notice the refinery in the distance.

Figure 3.7 The golf course to the west of 1200W in the “rural” area on the “Golf Course” route.

Figure 3.8 View looking to the west from 5600W in the “rural” area on the “Brighton Canal” route .

Figure 3.9 View looking to the east from 5600W in the “rural” area on the “Brighton Canal” route. Notice the warehouses in the distance.

Figure 3.10 Typical tree-lined street (900W) in a residential neighborhood along the “Golf Course” route.

Figure 3.11 View driving east on N. Temple (east of railroad tracks) in a commercial strip mall area.

Figure 3.12 View looking southeast at intersection of Redwood (Hwy. 68) and N. Temple on the "Golf Course" route. Leaving apartment residential area and entering strip mall area.

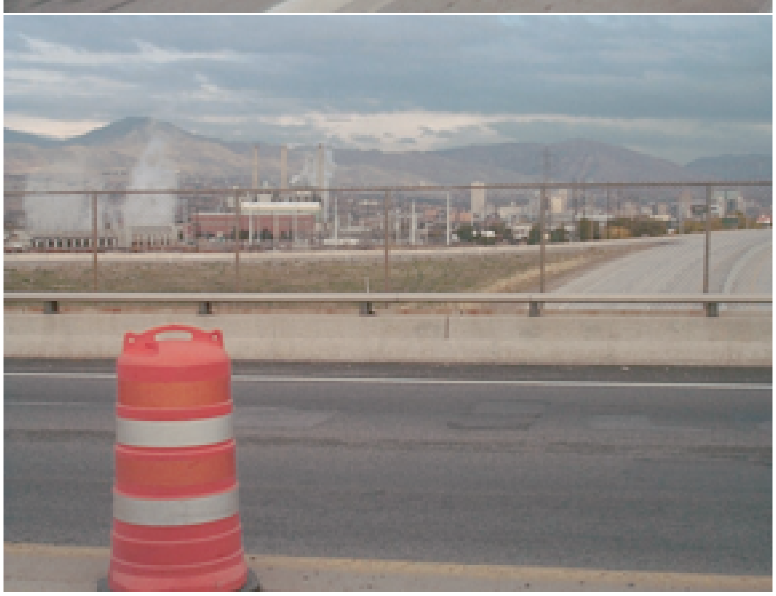

Figure 3.13 View looking west from Redwood (Hwy. 68) on the Highway 80 overpass. In the background is an electric power plant located between 80 and N. Temple.